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Comprehensive Consulting for the North American Energy Industry

Net Benefits of Solar Distributed Generation for the Public Service Company of Colorado

A Critique of Public Service Company of Colorado's DSG Benefit and Cost Study

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A Critique of
"Costs and Benefits of Distributed Solar Generation on the Public Service Company of Colorado System"

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On May 23, 2013, PSCo Services submitted to the Colorado Public Utilities Commission (Commission) a report on the costs and benefits of distributed solar generation (solar DG or DSG) on the electric system of Public Service Company of Colorado (PSCo). PSCo Services prepared this study (hereafter, the "Study") in response to Commission Decision No. C09-1223. The Vote Solar Initiative (VSI) retained Crossborder Energy to review the Study and, if appropriate, to provide alternative analyses based on our firm's experience in conducting similar studies in several other states. VSI has used the results of our critique to inform the comments on the Study which VSI filed, in conjunction with several other parties (the "Joint Solar Parties"), on September 9, 2013.

1. The Benefits of Solar DG

There is a significant, and growing, body of studies on the costs and benefits of solar DG. Many of these studies have been completed in the last several years. In addition, the Rocky Mountain Institute (RMI) recently completed a meta-analysis of this body of work in order to assess the common features and most significant differences among such studies.[1] For its meta-analysis, RMI developed a list of the benefits of solar DG typically analyzed in these studies. We have used this list as a starting point to assess PSCo's calculation of the benefits of solar DG. We present this list below, with our conclusion on the adequacy of the Study's analysis of each benefit listed. We explain further below our analysis of each of the benefits that PSCo either did not include or that we view as undervalued.

Table 1: *Summary of Benefits Assessed in PSCo's DSG Study*

Benefits to PSCo Ratepayers
Energy:
• Avoided energy purchases (including fuel purchases) **(Included in PSCo DSG study)**
• Avoided transmission and distribution line losses **(Undervalued in PSCo DSG study)**
Capacity:
• Avoided capacity purchases **(Undervalued)**
• Avoided transmission and distribution capacity investments, and operations and maintenance avoided costs **(Undervalued)**
Grid Support Services:
• Ancillary services, including reactive support and voltage control **(Not included)**
• Energy and generator imbalance **(Not included)**
• Synchronized and supplemental operating reserves **(Not included)**
• Scheduling, forecasting and system control and dispatch **(Not included)**

[1] Rocky Mountain Institute (RMI), "A Review of Solar PV Benefit and Cost Studies" (July 2013), available at http://www.rmi.org/PDF_empower_accurately_valuing_DER .

Financial Risk:

- Fuel price hedge **(Undervalued)**
- Avoided RPS generation purchases **(Not included)**

Security Risk:

- Reliability benefits (e.g. electricity grid resiliency) **(Not included)**

Environmental Risk:

- Avoided costs of current or future NO_x, SO_x, PM, & CO_2 regulatory costs **(Undervalued)**
- Reduced water usage in power production **(Not included)**
- Avoided land cost of avoided transmission or generating infrastructure **(Not included)**

Societal Benefits:

- Economic development impacts, including, impact on local and state tax revenues **(Not included)**
- Job creation **(Not included)**
- Avoided health impacts **(Not included)**

<u>Areas of Agreement with the Study's Assessment of Benefits</u>

We agree with important aspects of the Study's analysis of solar DG benefits. These include the following:

- **Long-term, 20-year analysis.** The benefits of solar DG should be calculated over a time frame that corresponds to the useful life of a solar DG system, which is 20 to 30 years. This treats solar DG on the same basis as other utility resources, both demand- and supply-side. When a utility assesses the merits of adding a new power plant, or a new energy efficiency (EE) program, the company will look at the costs to build and operate the plant or the program over their useful lives, compared to the costs avoided by not operating or building other resource options. PSCo's Study uses a 20-year time frame, and reports the results in terms of 20-year levelized $ per MWh values.

- **Comprehensive list of direct benefits.** Generally, PSCo considered a broad range of possible direct benefits of solar DG for non-participating ratepayers. As noted in the chart above and as explained further below, our concerns are principally that PSCo has undervalued a number of these benefits and that it has excluded consideration of broader societal and environmental benefits.

- **Avoided energy costs.** PSCo used a production cost model to estimate the long-term avoided energy costs of the 140 MW of solar DG now on its system. The results of this modeling (Figure 5 of the Study) show that the utility's marginal heat rate will gradually decline from about 9 MMBtu/MWh to 7 MMBtu/MWh, consistent with distributed solar generation displacing a blend of an efficient combined-cycle unit (roughly a 7 MMBtu/MWh heat rate) and a less efficient combustion turbine (roughly a 10 MMBtu/MWh heat rate), with combined cycle generation increasingly displaced over time as PSCo adds more efficient gas units. Avoided energy costs based on gas-fired generation make sense given PSCo's plans to retire coal units, convert others to gas, and to add new gas-fired combined cycle units.

Areas of Disagreement with the Study's Assessment of Benefits

There are five areas in which we have identified issues with PSCo's quantification of the benefits of solar DG. We discuss each of these below, and present our own calculations of each of these benefits.

1. **Avoided Generation Capacity Costs.** PSCo's calculation of the generation capacity costs avoided by solar DG features, in Appendix V, a new study of the Effective Load Carrying Capacity (ELCC) of the solar resources in its service territory. This analysis determines the firm capacity value of a solar DG resource, as a percentage of the resource's nameplate capacity. We have several concerns with this new ELCC analysis, including PSCo's admission to the poor quality of the solar data used,[2] the small sample of projects from which actual output data was obtained,[3] and whether PSCo maintained the necessary time correlation between the load and DG output data used in the ELCC study.[4] More fundamentally, PSCo has not explained why there should be such a dramatic drop in ELCC values compared to its prior 2009 ELCC study which used modeled solar production instead of actual data. Until these concerns are resolved, we recommend use of load duration (LD) data on solar output over the top 50 load hours on the PSCo system as a proxy for the ELCC results. These top 50 hours certainly are critical hours in terms of PSCo's capacity needs, and this data is far more transparent than the ELCC modeling. As shown in Table 2, the use of the LD metric produces capacity values that fall between the results of the two PSCo ELCC studies.

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2 ELCC Study, at pp. 8-9, and Study, at pp. 15-16.

3 For example, the Northern Front Range ELCC results for fixed arrays are based on just 3 projects with 2009 data and 5 projects with data from 2010. There is no actual data for the Southern Front Range for either fixed or tracking arrays, or for fixed systems on the Western Slope. ELCC Study, at Tables 4 and 5. It is questionable whether this data reflects the geographic diversity of the actual population of installed systems. In addition, the systems sampled are weighted more heavily toward those with a 10 degree tilt than the overall population of systems (see Study Tables 7, 9 and 10); a more representative weighting of systems with a 30 degree tilt would increase late afternoon output and could improve the ELCC metrics.

4 Table 12 of the Study shows that summer loads and solar DG output are positively correlated in Colorado. Given this result, one would expect use of actual output and loads would increase ELCCs, compared to 2009 results with modeled (i.e. TMY average) loads and outputs. Thus, the new results in the opposite direction are surprising. Page 6 of the ELCC Study notes that loads and solar output were manipulated to bring them up to 2013, and it is unclear whether this preserved the proper time correlation of this data.

Table 2: *Use of Load Duration Metric as a Compromise between ELCC Results*

Location	Weight	2009 ELCC	2013 ELCC	2013 LD
N. Front Range				
Fixed	79%	50%	31%	40%
Tracking	11%	59%	41%	52%
S. Front Range				
Fixed	5%	54%	32%	38%
Tracking	1%	64%	40%	51%
San Luis Valley				
Fixed	0%	51%	26%	35%
Tracking	4%	59%	47%	57%
Weighted Average	100%	52%	33%	42%

Many independent system operators use such load duration data to assess the capacity value of variable resources, and studies have shown that the load duration approach produces similar results to the much more complex, and less transparent, ELCC approach.[5]

PSCo's estimate of generation capacity costs relies, before 2017, on a bid that PSCo received for short-term capacity, and, after 2017, on data from PSCo's 2011 Energy Resource Plan (2011 ERP) on the annualized capital costs of a combustion turbine (CT). This perspective ignores the fact that PSCo's demand-side resources, including solar DG, are providing capacity to its system today, and the utility is relying on the sustained, steady growth of these demand-side resources, including distributed solar, to contribute to meeting its capacity needs before 2017. Without such continued growth in demand-side resources, the utility's need for supply-side resources would be advanced to close to the present. As a result, we believe that it is more accurate to use the full annualized costs of a CT as the value of generating capacity in all years of the analysis. This also recognizes the benefit of smaller-scale, short-lead-time resources compared to large central-station units that must be installed in large, "lumpy" increments and that often produce excess capacity for a number of years once they come on-line.

We also recommend that PSCo use the more comprehensive and detailed estimate of the capacity-related costs of a CT which the utility presented in its last rate case, and which PSCo used as a measure of its marginal generation capacity costs in designing its current rates. This estimate uses a Frame 7 Combustion Turbine (CT), includes associated

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5 See North American Electricity Reliability Corporation (NERC), Integration of Variable Generation Task Force, "Accommodating High Levels of Variable Generation" (April 16, 2009), at 39-41, discussing the load duration (capacity factor) approaches used by ISO New England, PJM, NY ISO, CAISO, and several utilities that operate control areas. This NERC report can be found at http://www.nerc.com/files/IVGTF_Report_041609.pdf. In addition, a Solar Electric Power Association (SEPA) report from May of 2008 – T. Hoff , R. Perez, J.P. Ross, and M. Taylor, "Photovoltaic Capacity Valuation Methods," available at http://www.solarelectricpower.org/media/84207/sepa%20pv%20capacity.pdf – compared the results from load duration vs. ELCC studies for three diverse utilities (Nevada Power, Rochester G&E, and Portland General Electric) over a range of PV penetration levels, and found that the load duration approach yielded capacity values at or below those derived from the ELCC method.

electric transmission and gas supply costs, adjusts for energy rents, and adds fixed operations and maintenance costs (O&M) and a 16.3% planning reserve margin.[6]

Table 3: *Calculation of Generation Capacity Cost Avoided by Solar DG*

Line	**Component**	**Value**	*Units*
1	Marginal Generation Capacity Cost (2014 $)	$180.62	*per kW-year*
2a	Solar PV Capacity Value, per LD Metric	42%	
2b	*Assuming 0.85 kW-AC per kW-DC*	49%	
3	Generation Capacity Cost Avoided by DSG	$89.25	*per kW-year*
4a	Annual PV Output per kW-DC	1,500	*kWh per year*
4b	*Assuming 0.85 kW-AC per kW-DC*	1,765	*kWh per year*
5a	Generation Capacity Cost Avoided by DSG	$0.051	*per kWh*
5b		$50.57	*perMWh*

As shown in Table 3, we use the load duration data to estimate solar PV's capacity value per kW of nameplate capacity and PSCo's more comprehensive estimate of CT costs from its rate case. This produces an avoided generation capacity cost of $50.57 per MWh, substantially higher than the comparable number that PSCo presents in its Study.

2. **Avoided Emissions Costs.** The Study includes the benefit of the greenhouse gas (GHG) emissions avoided by solar DG, based on the results of the production cost model including the 59 MW and 140 MW levels of DSG and using the 2011 ERP's blend of forecasted CO_2 emissions prices from three sources. This blended price is roughly $15.75 per short ton in 2021, escalating at about 7% per year and resulting in a 20-year levelized avoided GHG emissions cost of $5.10 per MWh of solar DG output.

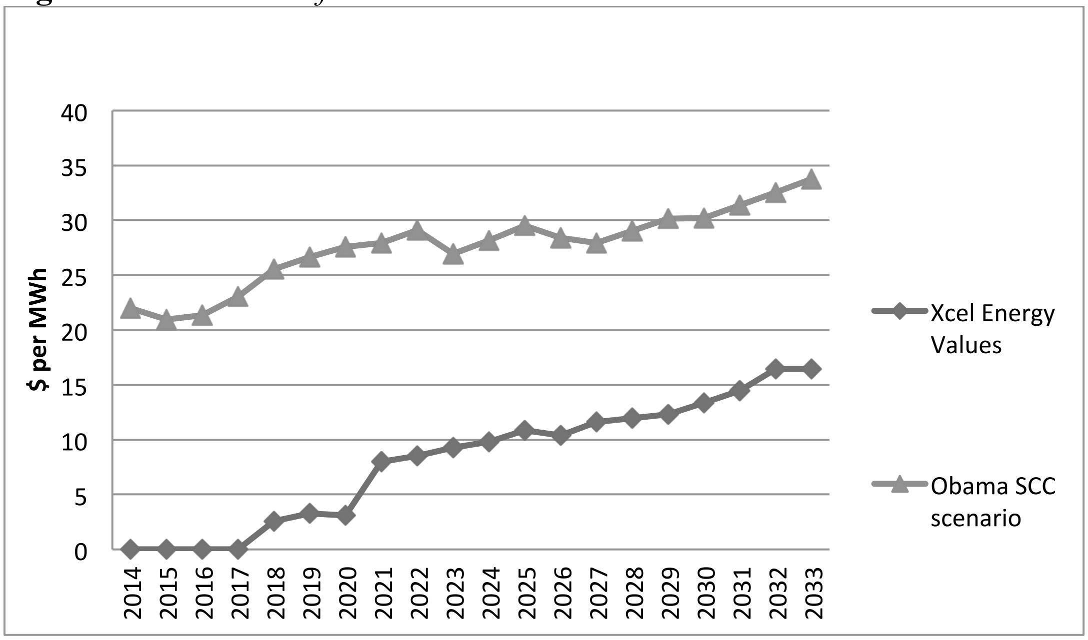
   The federal government has announced that it will prioritize reductions of greenhouse gas (GHG) emissions by focusing on reducing pollution from electric power generation. This effort will employ a Social Cost of Carbon (SCC), with a base scenario of a carbon cost of $35 per metric ton CO_2 in 2012 (in 2007 $), growing at 2.1% per year plus inflation through 2050.[7] Given this development, we believe that the avoided cost methodology which PSCo employs underestimates the risk of a higher price on greenhouse gas (GHG) emissions in the near future. We recommend consideration of a high CO_2 price scenario, just as there is a high price case for natural gas. Further, this scenario should use an earlier start date than 2017 or 2021 for CO_2 emissions costs. We have developed a High GHG Price Scenario that uses the SCC values, that assigns a cost to CO_2 emissions beginning in 2014, and that converts the gas-equivalent CO_2 prices (in $/MMBtu) to an energy price (in $/MWh) using the natural gas-based marginal heat rates shown Figure 5 of the Study. This High GHG case increases the levelized avoided

[6] The details of this calculation are presented in Mr. Scott B. Brockett's testimony for PSCo in the utility's last rate case (Docket No. 09AL-299E), at pages 12-21 and Exhibit SBB-5. Mr. Brockett calculates the Company's marginal generation capacity costs as $163.63 per kW-year (excluding 7.69% losses), based on the annualized fixed, capacity-related costs of a new combustion turbine (CT). Escalated to 2014 $ at 2.5% per year, this cost in 2014 is $180.62 per kW-year.

[7] See http://www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf at page 18.

emissions costs shown in Table 16 of the Study from $5.10 per MWh to $24.80 per MWh. Figure 1 compares these two GHG price scenarios, in terms of $ per MWh.

Figure 1: *Scenarios for Avoided GHG Emissions Costs*



3. **Avoided Ancillary Service Costs.** The majority of the output of solar DG systems will serve the on-site load of the DG host customer; the rest will run the customer's meter backward when power is exported. As a result, solar DG reduces the loads that PSCo will serve. Western Electricity Coordinating Council (WECC) reliability standards require control area operators to maintain operating reserves (spinning and non-spinning) equal to 7% of the load served by thermal generation and 5% of the load served by hydro resources.[8] As a result, load reductions from solar DG will reduce PSCo's requirements to procure operating reserves. In regions where ancillary services are procured in open and transparent markets, operating reserve costs are typically 1% of overall energy costs.[9] We recommend that PSCo include these avoided ancillary service costs in the final Study.

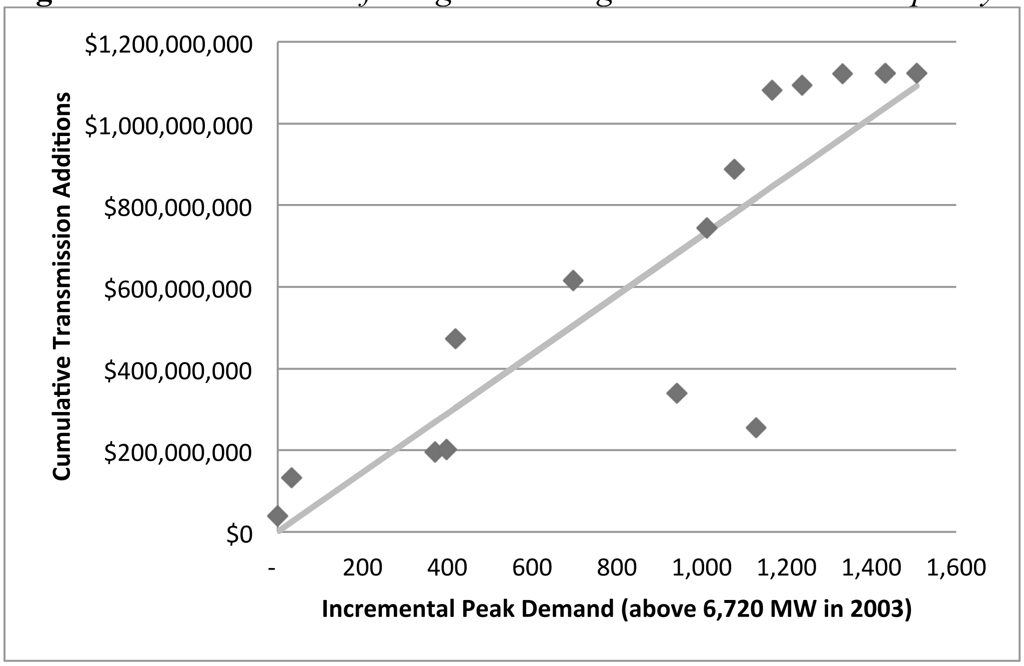
4. **Avoided Transmission Costs.** Most, if not all, solar DG output is either consumed behind the meter or on the distribution system by the neighbors of the DG system, and never touches the transmission system. Solar DG thus clearly reduces the use of the transmission system, and will reduce peak demands on the PSCo transmission system even if solar output and peak demand are not perfectly correlated. The Study fails to consider that peak load reductions from solar DG will allow PSCo to avoid future

[8] This requirement also can be based on the largest single contingency, if it is higher. In most control areas, the load-based requirement is higher.

[9] For example, 1% of avoided energy costs is the metric for avoided ancillary service costs used in the California net metering and California Solar Initiative cost-benefit studies. See also California Independent System Operator, *2012 Annual Report on Market Issues and Performance*, at 116 and Figure 5-1, showing average ancillary service costs as a percentage of wholesale energy costs from 2008-2012.

load-related transmission investments. We have calculated PSCo's long-term marginal transmission capacity costs using the industry-standard NERA regression method used by many utilities to determine their marginal transmission and distribution capacity costs.[10] **Figure 2** shows the regression fit of cumulative transmission capital additions as a function of incremental demand growth.

Figure 2: *Calculation of Long-term Marginal Transmission Capacity Costs*



We convert the regression slope of $725 per kW using a real economic carrying charge of 7.5% that follows the methodology outlined in the 2011 ERP. Our estimate of annualized marginal transmission costs for PSCo is $55.20 per kW-year, or about $65.30 per kW-year after including a loader for the annual transmission O&M costs (also based on FERC Form 1 data). Finally, we assume that each kW-DC of solar DG capacity reduces PSCo's peak demand by 0.42 kW (from the LD metrics) and convert avoided transmission capacity costs to $ per MWh of solar DG output assuming an average annual output of 1,765 kWh per kW-AC. **Table 4** shows this calculation, which results in $18.28 per MWh of the transmission capacity costs avoided by solar DG.

[10] The NERA regression model fits incremental transmission costs to demand growth. The slope of the resulting regression line provides an estimate of the marginal cost of transmission associated with a change in load. The NERA methodology typically uses 10-15 years of historical expenditures on transmission and peak transmission system load, as reported in FERC Form 1, and a five-year forecast of future expenditures and load growth. Crossborder's analysis used PSCo's FERC Form 1 data for the most recent 10 years (2003-2012), and a forecast of transmission project costs over the five years (2013-2017) based on data from the Colorado Coordinated Planning Group's 10-year plan.

Table 4: *Calculation of Transmission Capacity Costs Avoided by Solar DG*

Line	**Component**	**Value**	*Units*
1	Marginal Transmission Capacity Cost (2014 $)	$65.30	*per kW-year*
2a	Solar PV Capacity Value, per LD Metric	42%	
2b	*Assuming 0.85 kW-AC per kW-DC*	49%	
3	Transmission Capacity Cost Avoided by DSG	$32.27	*per kW-year*
4a	Annual PV Output per kW-DC	1,500	*kWh per year*
4b	*Assuming 0.85 kW-AC per kW-DC*	1,765	*kWh per year*
5a	Generation Capacity Cost Avoided by DSG	$0.018	*per kWh*
5b		$18.28	*perMWh*

5. **Avoided Line Losses.** Solar DG also reduces transmission line losses. It avoids these costs on a marginal basis, by displacing the last, marginal increments of power flowing on the transmission system. Thus, solar DG should be credited with the benefit of reducing marginal, not average, losses over the hours in which solar DG operates. Based on the derivative of PSCo's equation for its average system losses (see Study, Figure 10 on page 39), solar DG allows PSCo to avoid 4.2% transmission line losses, about 1.7% greater than calculated in the Study.

We present below revised versions of the Study's summary Table 1 that are based on the re-calculations of the Study's results presented above. **Table 5** below includes the Joint Parties' proposed changes to the PSCo Study results with no change to the forecast of GHG costs.

Table 5: *Revised Version of Study Summary Table 1 – **Base GHG***

Benefit / (Cost)	**Low Gas**		**Base Gas**		**High Gas**	
	$/MWh	*%*	*$/MWh*	*%*	*$/MWh*	*%*
Avoided Energy Costs	35.80	*28%*	52.10	*36%*	76.10	*44%*
Fuel Hedge Value	6.60	*5%*	6.60	*5%*	6.60	*4%*
Avoided Emissions	5.10	*4%*	5.10	*4%*	5.10	*3%*
Avoided Ancillary Services	0.40	*0%*	0.50	*0%*	0.80	*0%*
Avoided Generation Capacity	50.60	*40%*	50.60	*35%*	50.60	*29%*
Avoided Distribution	0.50	*0%*	0.50	*0%*	0.50	*0%*
Avoided Transmission	18.30	*14%*	18.30	*13%*	18.30	*11%*
Avoided Line Losses	9.50	*7%*	11.40	*8%*	13.90	*8%*
(Solar Integration Costs)	(0.50)		(1.80)		(4.40)	
Net Benefits / (Costs)	**126.30**	*100%*	**143.30**	*100%*	**167.50**	*100%*
PSCo Study Values	63.90		80.20		103.90	
% Change	*98%*		*79%*		*61%*	

As discussed above, we also have added a High GHG Cost case, presented in **Table 6**, which uses the Administration's social cost of carbon values.

Table 6: *Revised Version of Study Summary Table 1 – **High GHG***

Benefit / (Cost)	Low Gas		Base Gas		High Gas	
	$/MWh	*%*	*$/MWh*	*%*	*$/MWh*	*%*
Avoided Energy Costs	35.80	*24%*	52.10	*31%*	76.10	*39%*
Fuel Hedge Value	6.60	*4%*	6.60	*4%*	6.60	*3%*
Avoided Emissions	24.80	*17%*	24.80	*15%*	24.80	*13%*
Avoided Ancillary Services	0.40	*0%*	0.50	*0%*	0.80	*0%*
Avoided Generation Capacity	50.60	*34%*	50.60	*30%*	50.60	*26%*
Avoided Distribution	0.50	*0%*	0.50	*0%*	0.50	*0%*
Avoided Transmission	18.30	*12%*	18.30	*11%*	18.30	*9%*
Avoided Line Losses	11.40	*8%*	13.30	*8%*	15.90	*8%*
(Solar Integration Costs)	(0.50)		(1.80)		(4.40)	
Net Benefits / (Costs)	**147.90**	*100%*	**164.90**	*100%*	**189.20**	*100%*
PSCo Study Values	63.90		80.20		103.90	
% Change	*131%*		*106%*		*82%*	

The avoided cost benefits of solar DG shown in these revised tables do not include a number of more difficult-to-quantify benefits, which will reduce long-term costs for PSCo ratepayers. These additional benefits include:

1. **Price mitigation benefits.** Lower demand for electricity (and for the gas used to produce the marginal kWh of power) has the broad benefit of lowering prices across the gas and electric markets in which PSCo operates.[11] On the electric side, these benefits are difficult to quantify because PSCo does not operate in a market with transparent, hourly locational marginal prices.

2. **Grid security.** Renewable DG resources are installed as many small, distributed systems and thus are highly unlikely to fail at the same time. They are also located at the point of end use, and thus reduce the risk of outages due to transmission or distribution system failures. This reduces the economic impacts of power outages for utility ratepayers.

3. **Avoided Renewables Costs.** It is critical that the avoided cost benefits of DSG be calculated assuming that, in the absence of DSG, PSCo would have to supply the same product received by customers who install DSG. DSG supplies a 100% renewable product, with a renewable content far higher than PSCo is required to provide under the

[11] For example, a Lawrence Berkeley National Lab study has estimated that the consumer gas bill savings associated with increased amounts of renewable energy and energy efficiency, expressed in terms of $ per MWh of renewable energy, range from $7.50 to $20 per MWh. Wiser, Ryan; Bolinger, Mark; and St. Clair, Matt, "Easing the Natural Gas Crisis: Reducing Natural Gas Prices through Increased Deployment of Renewable Energy and Energy Efficiency" (January 2005), at ix, http://eetd.lbl.gov/EA/EMP .

Colorado Renewable Energy Standard (RES). Through the availability of NEM and privately-financed DSG, PSCo avoids the costs to meet some of the customer demand for a 100% renewable product. Accordingly, distributed solar has value in reducing PSCo's costs for additional renewable generation even though the utility has met its RES requirements for a number for years into the future. In this respect, solar DSG customers are similar to PSCo customers who obtain power with up to a 100% renewable content through the utility's Windsource green pricing program, except that PSCo does not incur the Windsource cost premium to serve them.

The first two of these benefits have been calculated separately in at least one study, which estimated these benefits collectively to be from $58 to $92 per MWh (20-year levelized) in several eastern U.S. markets.[12] A metric for the value of a higher penetration of renewable generation on the PSCo system would be the cost premium associated with PSCo's Windsource program in Colorado, currently $21.60 per MWh. PSCo is proposing in its 2014 Renewable Energy Standard Compliance Plan (Docket No. 13A-0836E – the "2014 RES Plan") to reduce this premium to $15.00 per MWh. Windsource allows customers to be served with a higher penetration of renewable generation than is available through PSCo's system supply, whose renewable content is driven by the Colorado RES requirement.

Table 7 summarizes these potential additional societal and environmental benefits. We note that these additional benefits are not necessarily additive. For example, one can argue that ratepayers will obtain the price mitigation and grid security benefits of renewables through purchasing a higher penetration of renewable power – the cost of which is represented by the avoided 100% renewables costs.

Table 7: *Potential Additional Benefits of DSG*

Benefit	Magnitude
	20-yr levelized $ per MWh
Price mitigation	$35 - $69
Grid security	$22 - $23
Avoided 100% Renewables Costs	$15 - $22*

** Current value, not a 20-year levelized number.*

2. Costs of Solar DG

Although not presented in the Study, PSCo has provided analysis of the cost side of the equation in its 2014 RES Plan. The primary costs of solar DG are the retail rate credits provided to solar customers through net metering, i.e. the revenues that the utility loses as a result of DG customers serving their own load. All ratepayers also pay the utility's calculated costs to integrate intermittent solar generation into the grid (which are included above as a deduction to the benefits of solar DG). PSCo has estimated the long-term, 20-year lost revenues associated with existing solar customers in its Colorado service territory, in its 2014 RES Plan testimony.[13]

[12] Hoff, Norris, and Perez, *The Value of Distributed Solar Electric Generation to New Jersey and Pennsylvania* (November 2012), at Table ES-2.
[13] Docket No. 13A-0836E, Testimony of Scott B. Brockett, especially Exhibit SBB-1.

Based on this data, Table 7 summarizes PSCo's lost revenues by customer class on a 20-year levelized basis using the company's 7.60% discount rate.

Table 8: *PSCo's Lost Revenues by Customer Class*

Customer Class	Lost Revenues
	20-yr levelized $ per MWh
Residential (R)	123.30
Small Commercial (C)	117.30
Secondary General (SG)*	99.70
Primary General (PG)*	104.30

** PSCo's SG and PG rates include demand charges that are included in these lost revenue calculations. As solar customers have difficulty avoiding demand charges, the lost revenues for these classes appear to be overstated.*

3. Net Benefits or Costs of Solar DG

The net benefits or costs of solar DG, ignoring the additional difficult-to-quantify benefits noted in Table 7, are the difference between the benefits summarized in Tables 5 and 6 and the costs shown in Table 8. These net benefits are summarized in **Tables 9 and 10**, which show the net benefits in terms of both 20-year levelized $ per MWh and in terms of annual dollars. The annual dollar numbers are based on the estimated annual output of the 140 MW of solar DG now installed on the PSCo system.[14]

Table 9: *Summary of Net Benefits of Solar DG – **Base GHG***

	Benefits	Costs	Net Benefits	Output	Total
	$/kWh	*$/kWh*	*$/kWh*	*MM kWh/yr*	*MM$/yr*
Residential (R)	0.1433	0.1233	0.0200	66.7	$1.3
Small Commercial (C)	0.1433	0.1173	0.0260	9.4	$0.2
Secondary General (SG)	0.1433	0.0997	0.0436	97.4	$4.3
Primary General (PG)	0.1433	0.1043	0.0390	21.6	$0.8
Total				195.2	**$6.7**

Table 10: *Summary of Net Benefits of Solar DG – **High GHG***

	Benefits	Costs	Net Benefits	Output	Total
	$/kWh	*$/kWh*	*$/kWh*	*MM kWh/yr*	*MM$/yr*
Residential (R)	0.1649	0.1233	0.0416	66.7	$2.8
Small Commercial (C)	0.1649	0.1173	0.0476	9.4	$0.5
Secondary General (SG)	0.1649	0.0997	0.0652	97.4	$6.4
Primary General (PG)	0.1649	0.1043	0.0606	21.6	$1.3
Total				195.2	**$10.9**

14 We estimated this output by scaling up the output from the initial 59 MW of solar DG to the full 140 MW, using the data on output by customer class reported in Table 4 of the Study and the distribution of solar customers by customer class shown in Table 8. We have not included the small number of transmission-level solar customers, because PSCo has not calculated lost revenues for this class.

4. Conclusion

According to our analysis, DSG provides net benefits to PSCo, and thus its ratepayers. The annual net benefits of solar DG on the PSCo system range from $6.7 million per year in the Base GHG case to $10.9 million per year assuming a High scenario for GHG allowance prices.